Large-scale Coordinated Platooning of Heavy-duty Vehicles

Jeffrey Larson Christoph Kammer
Kuo-Yun Liang Karl H. Johansson

KTH Royal Institute of Technology

JANUARY 17, 2014

Problem Statement

Goal

minimize	Total Fuel Use
such that	Vehicles Arrive on Time

Using the fact that vehicles travelling in a platoon consume less fuel than when travelling independently

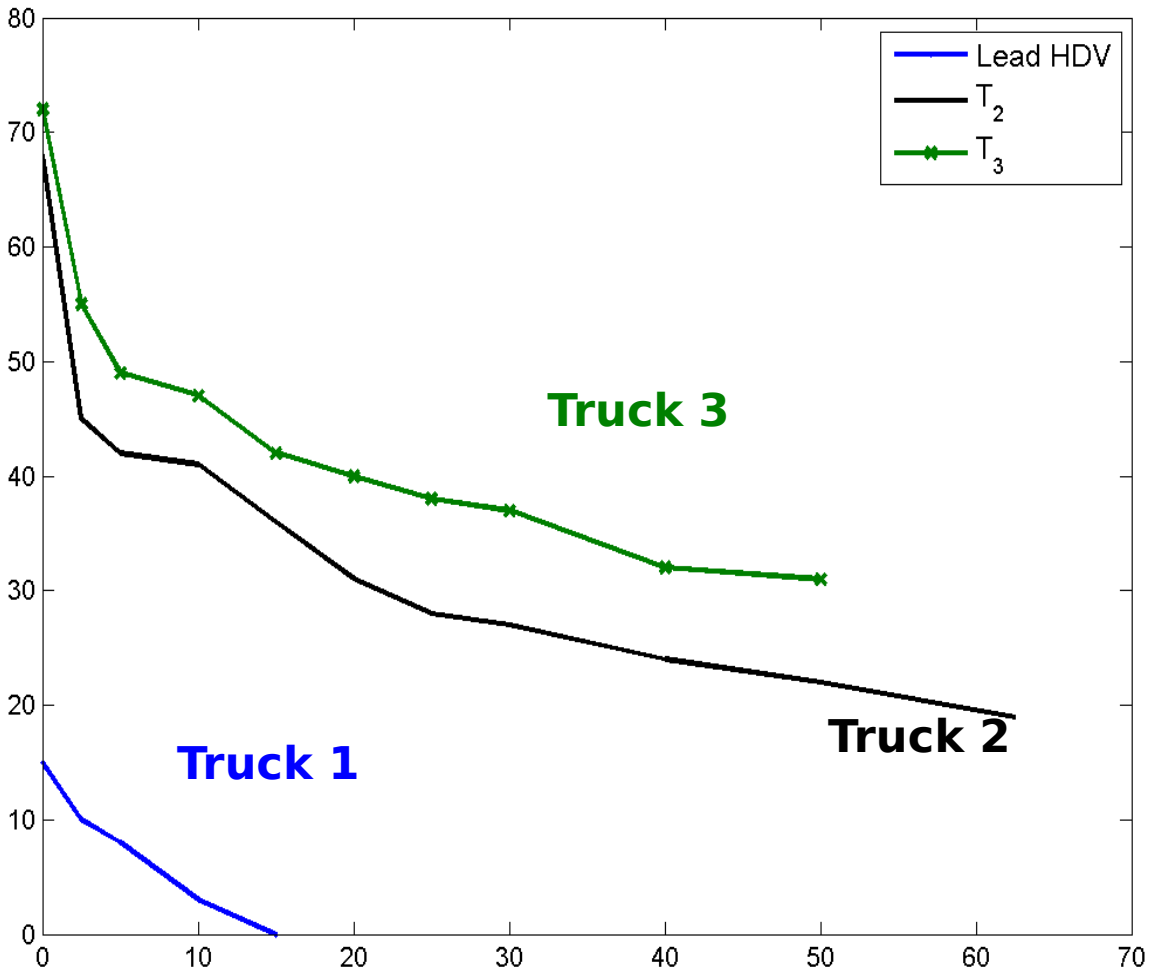
What is a Platoon?

What is a Platoon?

What is a Platoon?

Approximately 30% of an HDV's life costs is fuel.

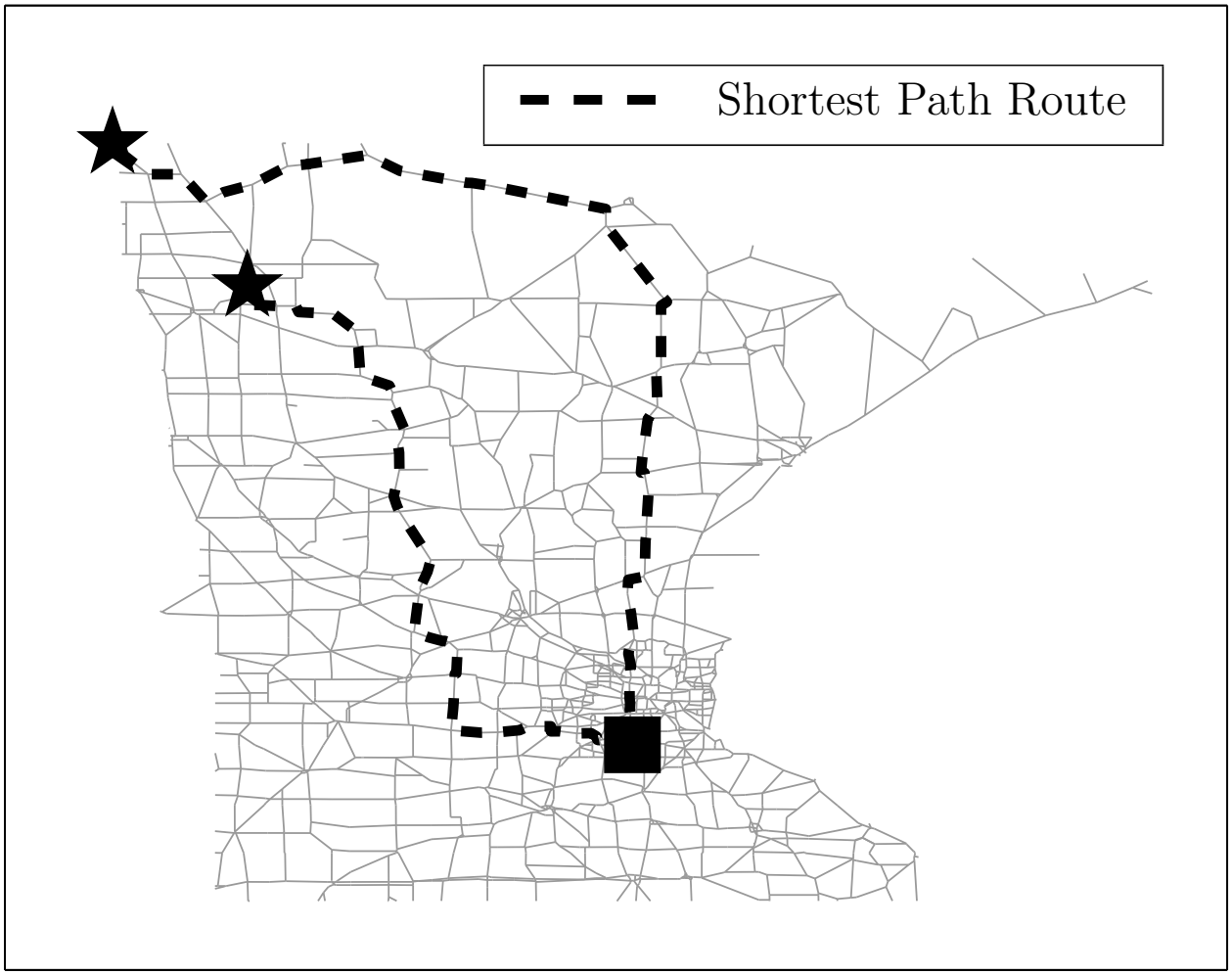
Platooning Fuel Savings



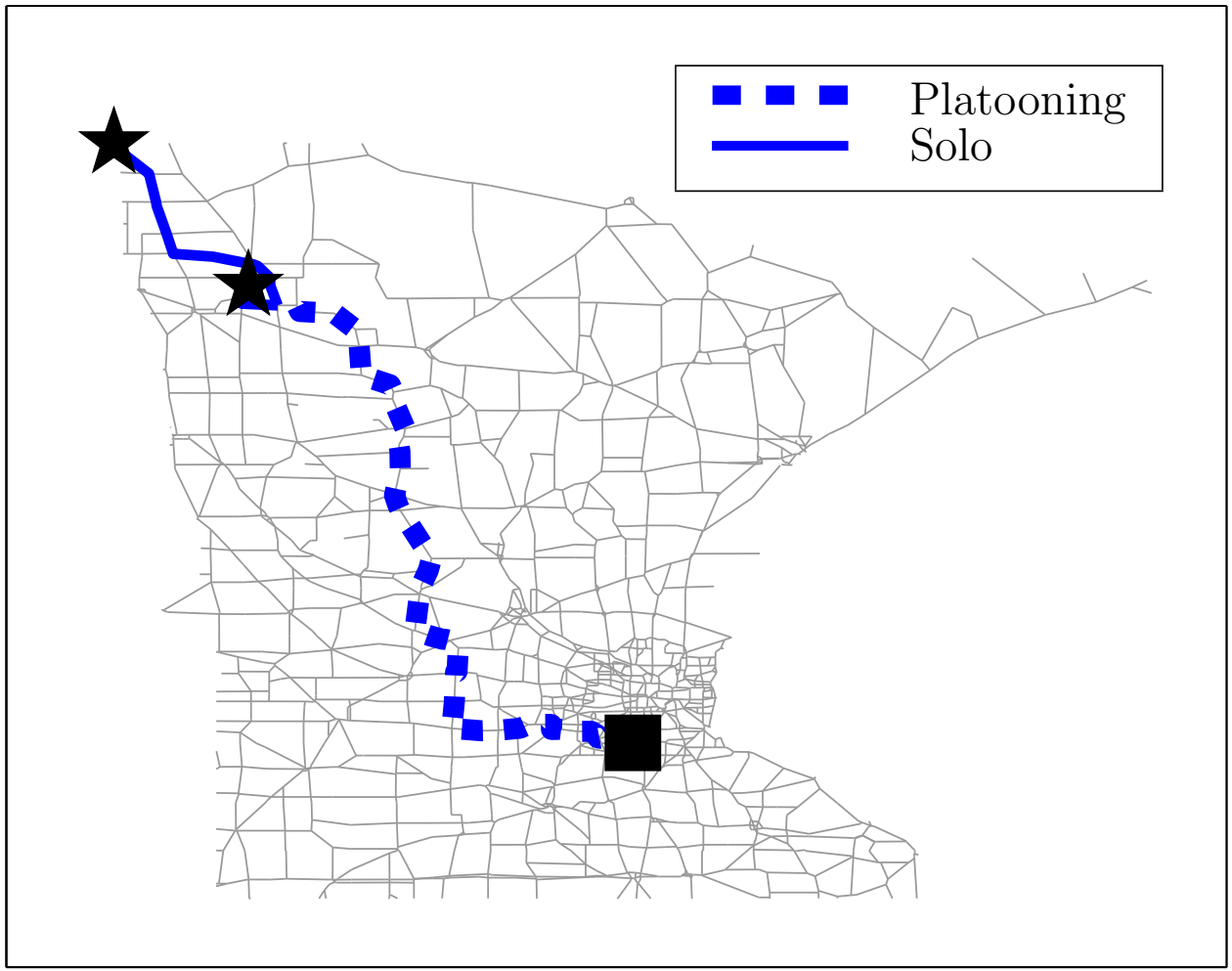
Previous Work

- 1966 – W. Levine and M. Athans, "On the Optimal Error Regulation of a String of Moving Vehicles"
- 1995 – M. Zabat, N. Stabile, S. Farascaroli, F. Browand, "The Aerodynamic Performance Of Platoons" UC Berkeley: California Partners for Advanced Transit and Highways (PATH)
- 2010 – T. Robinson, E. Chan, and E. Coelingh, "Operating Platoons on Public Motorways: An Introduction to the SARTRE Platooning Programme"

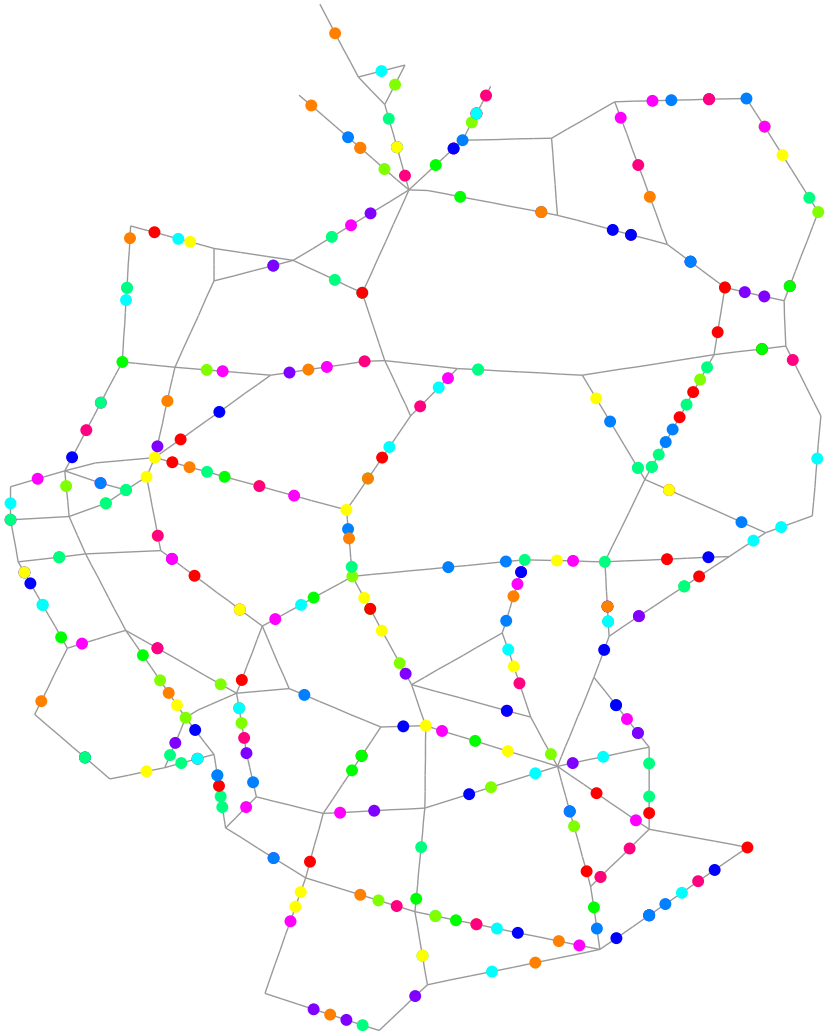
Fundamental Concept



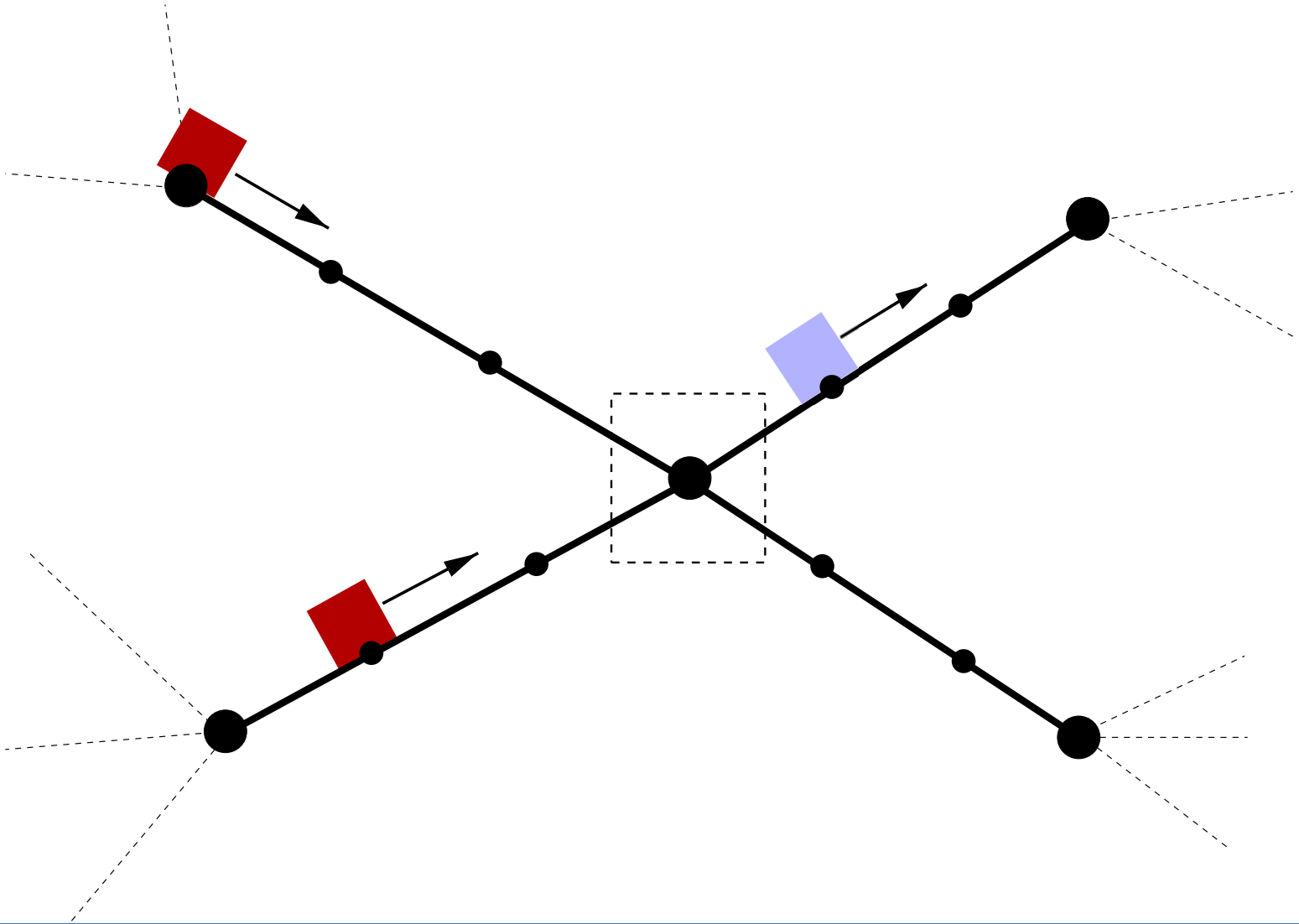
Fundamental Concept



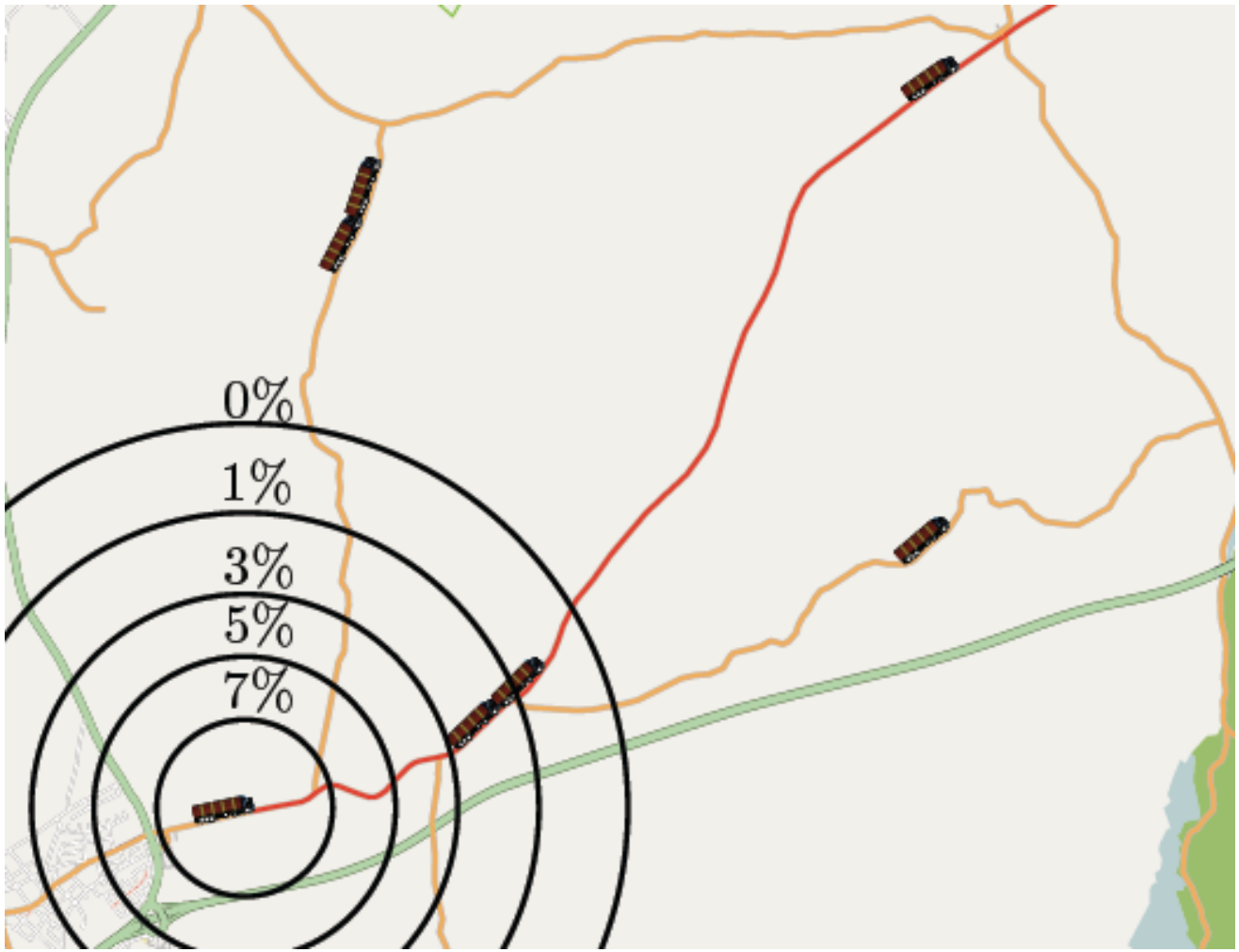
Difficult Problem



Local Controller



Catching Up



Pseudocode

Algorithm: Logic for the local controller

if *Approaching HDVs can feasibly adjust their speeds to form a platoon* **then**
    if *Test of sufficient savings* **then**
        Inform the HDVs to adjust their speeds to form a platoon
    end
end

Pseudocode

Algorithm: Logic for the local controller

if *Approaching HDVs can feasibly adjust their speeds to form a platoon* **then**
  if *Test of sufficient savings* **then**
    Inform the HDVs to adjust their speeds to form a platoon
  end
end

Notation:

- Represent our network with a graph $G = (V, E)$.
- Denote the control node s and let d_n be the destination for HDV n.
- Let $D(i, j)$ be the fuel used travelling from vertex i to vertex j.
- Let m_n be the allowed detour for HDV n.
- Let η be the percentage of fuel saved by platooning.

Pseudocode

Algorithm: Savings calculation for two HDVs

$N_s \leftarrow s$; $Best \leftarrow D(s, d_1) + D(s, d_2)$;

$m_i \leftarrow 0 \; \forall i$;

for ν *in* V **do**

  if $((2-\eta)D(s,\nu) + D(\nu, d_1) + D(\nu, d_2) < Best)$ &
  $(D(s,\nu) + D(\nu, d_1) \leq D(s, d_1) + m_1)$ &
  $(D(s,\nu) + D(\nu, d_2) \leq D(s, d_2) + m_2)$ **then**

    $N_s \leftarrow \nu$;

    $Best \leftarrow (2-\eta)D(s,\nu) + D(\nu, d_1) + D(\nu, d_2)$;

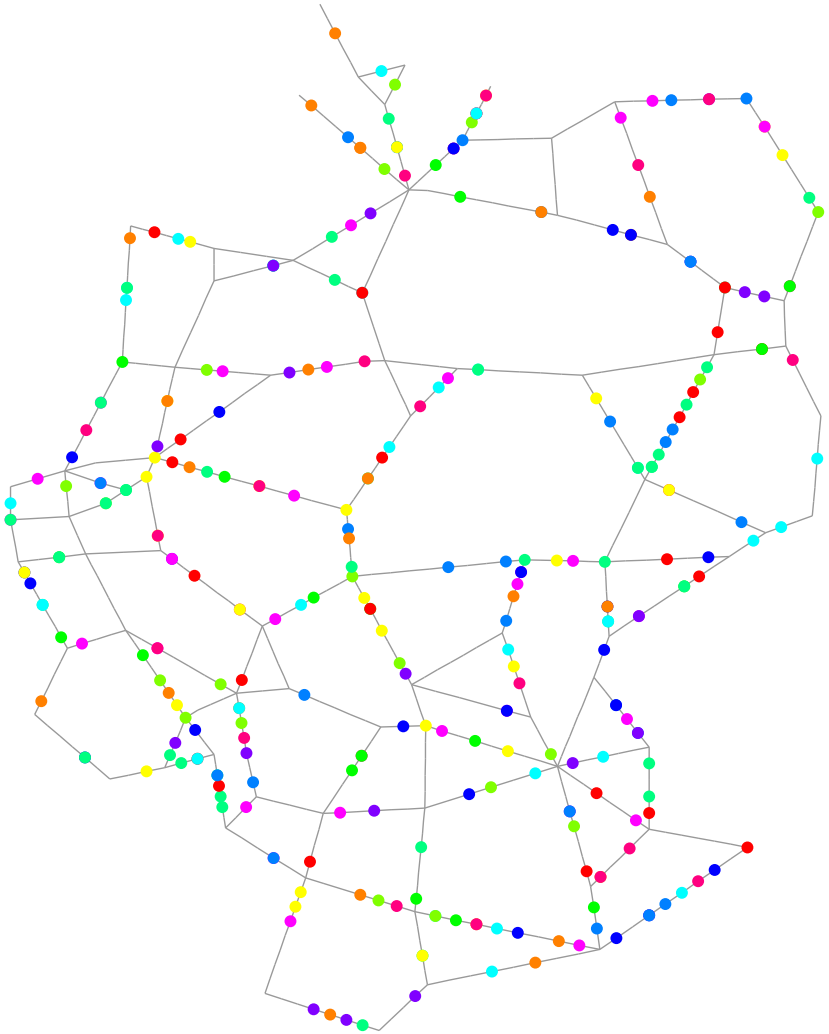
    Update m_1 or m_2 if needed;

  end

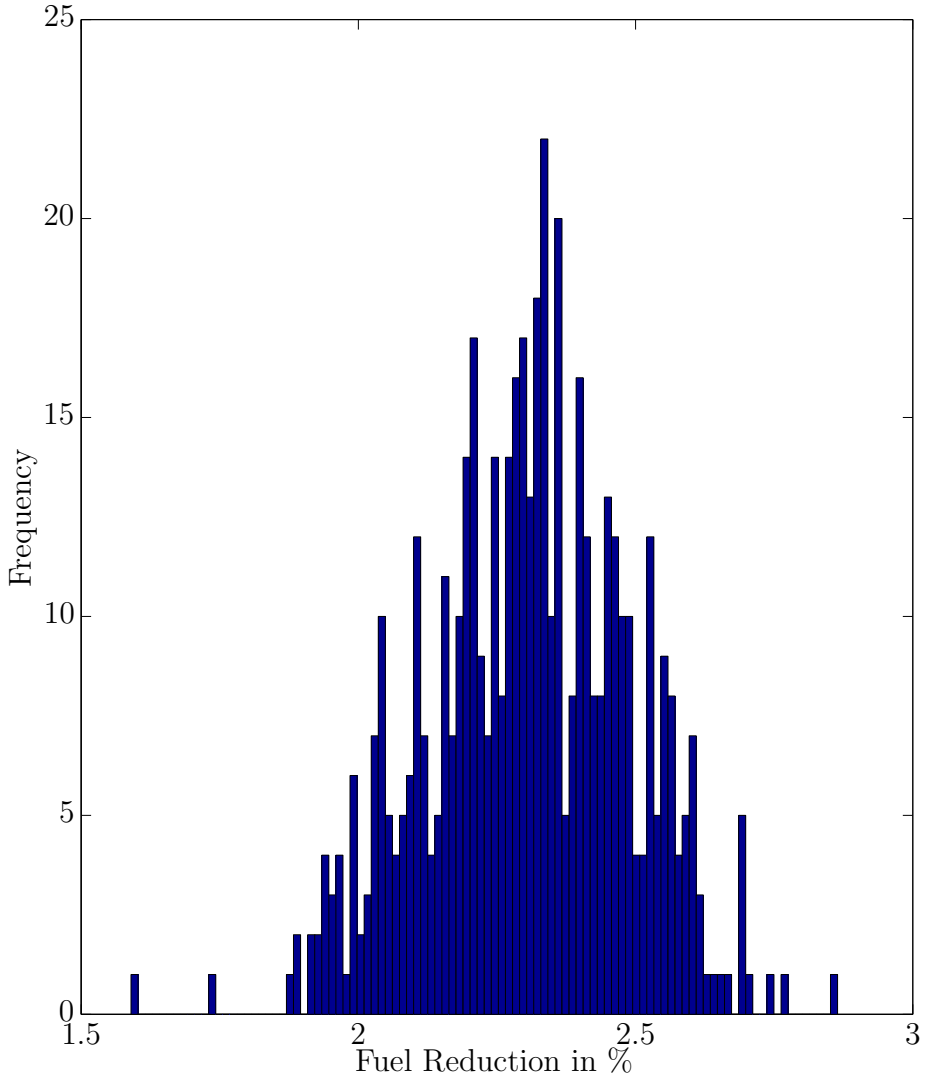
end

$Savings = D(s, d_1) + D(s, d_2) - Best$;

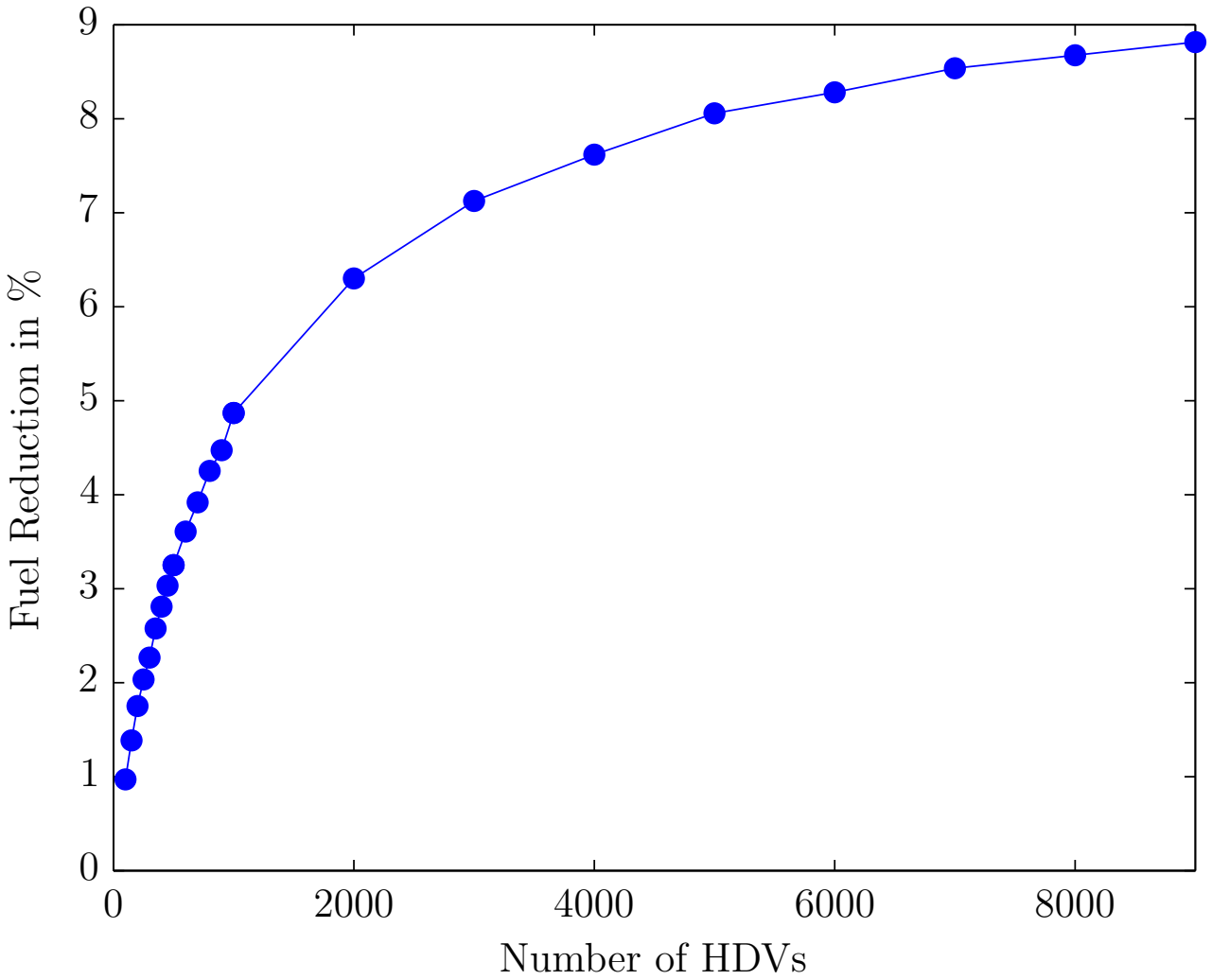
Savings



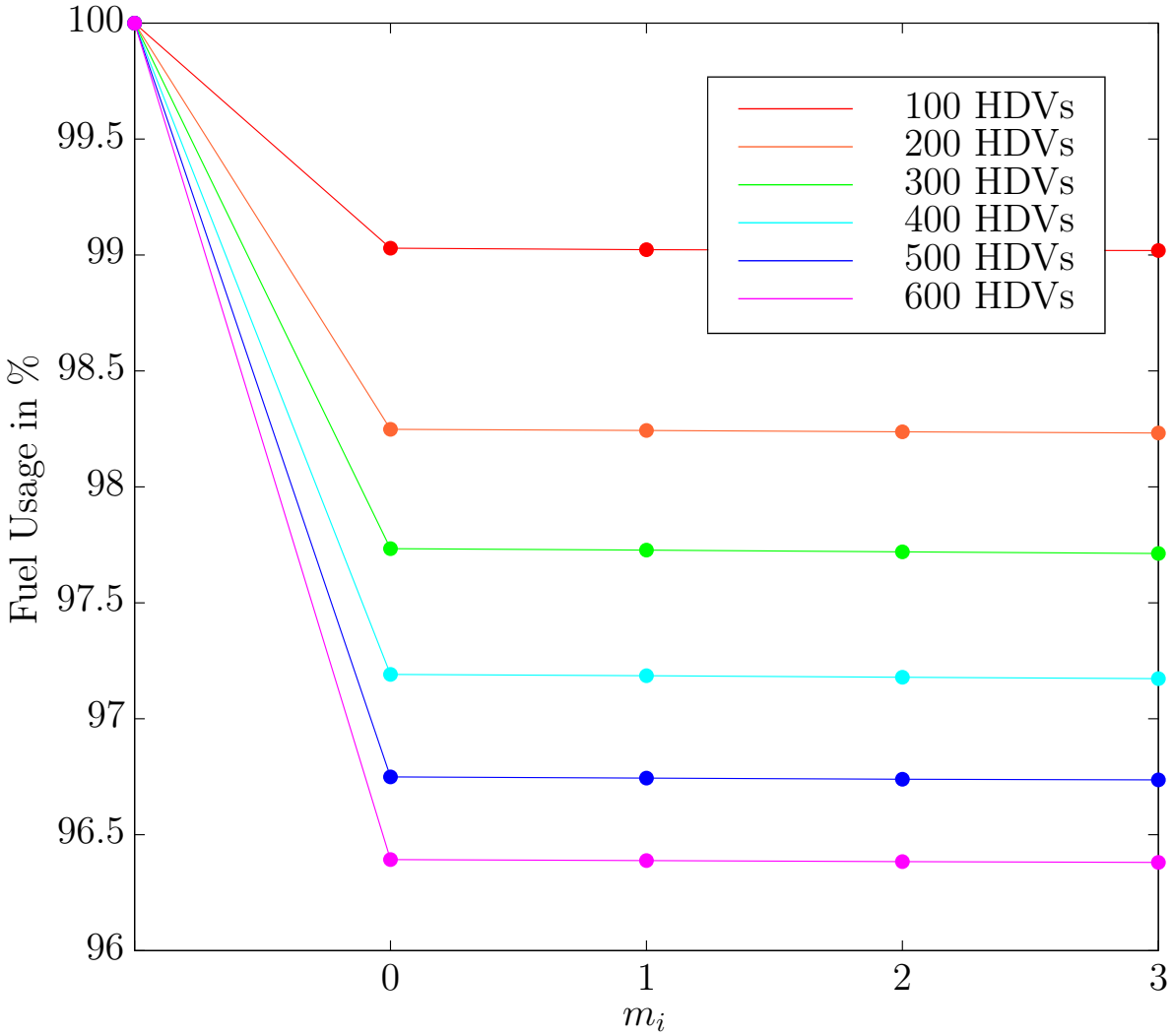
Savings



Savings


Fuel Reduction in %
Number of HDVs
0
1
2
3
4
5
6
7
8
9
0
2000
4000
6000
8000

Increasing possible detours



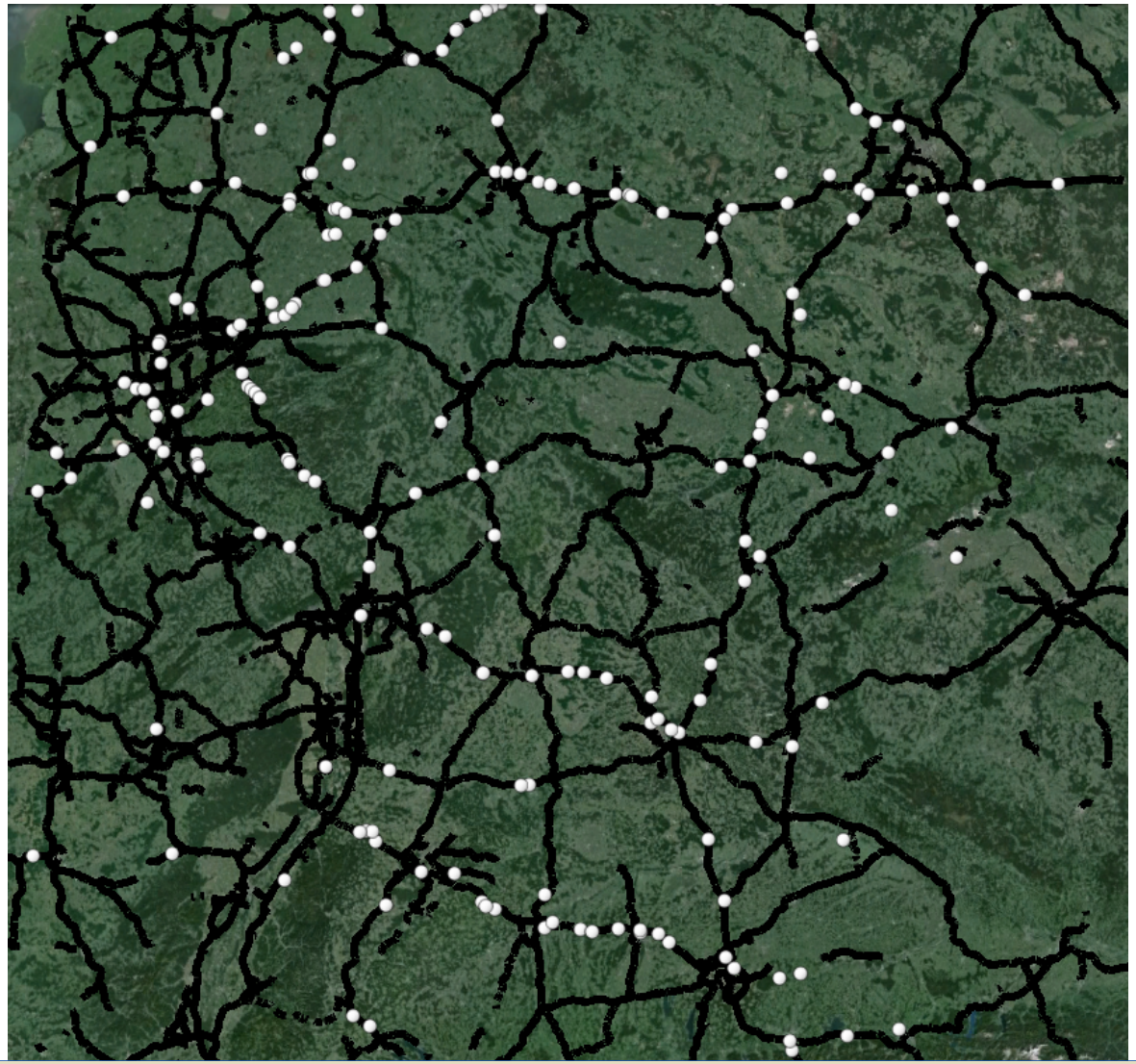
Conclusion & Current Work

It is possible to reduce fuel use by 5%
when coordinating 1000 HDVs on the German Autobahn.

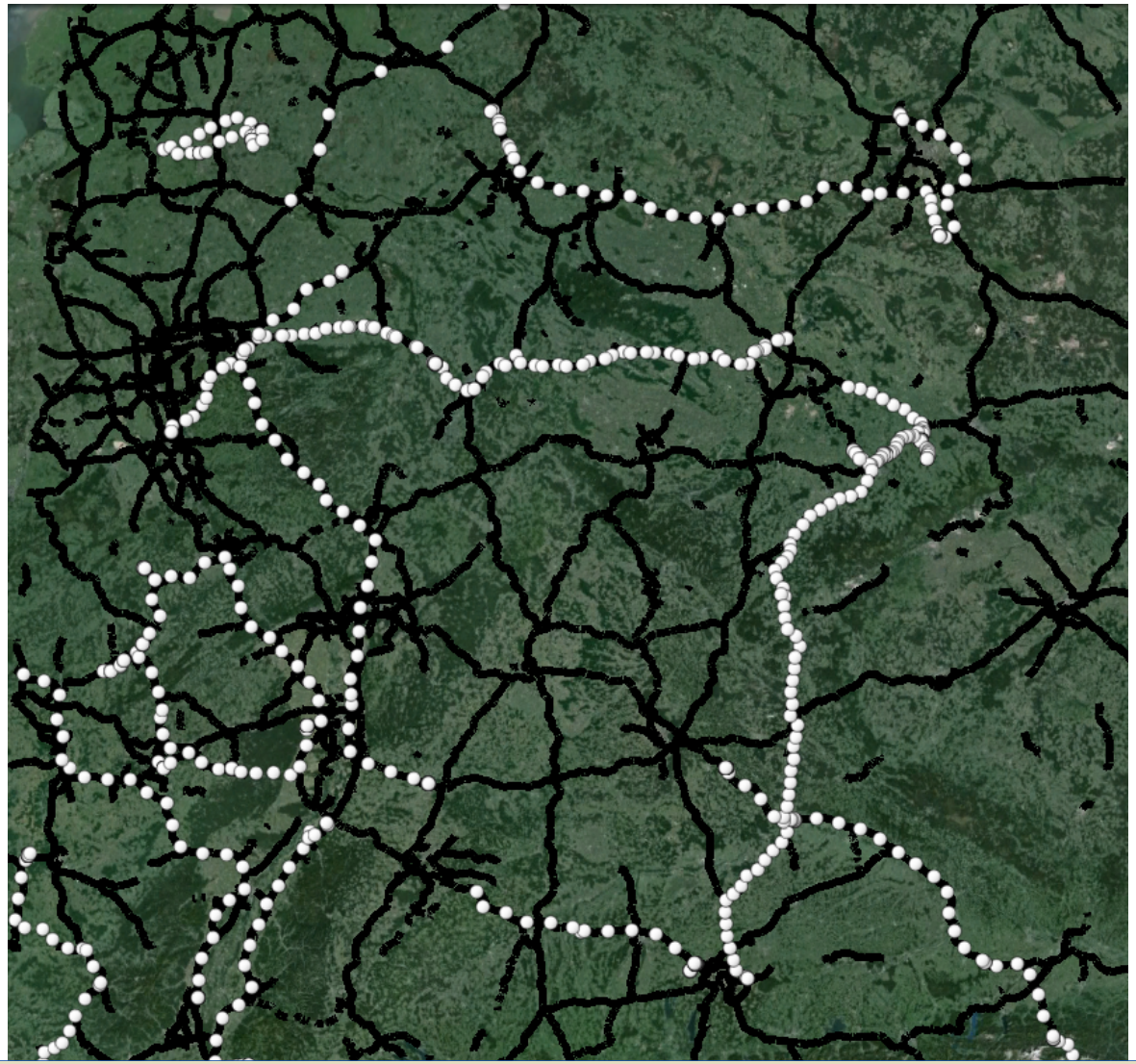
Work is ongoing:

- Platooning when traffic is time dependent.
- Accounting for breaks and legal requirements
- Continue with real-world experiments

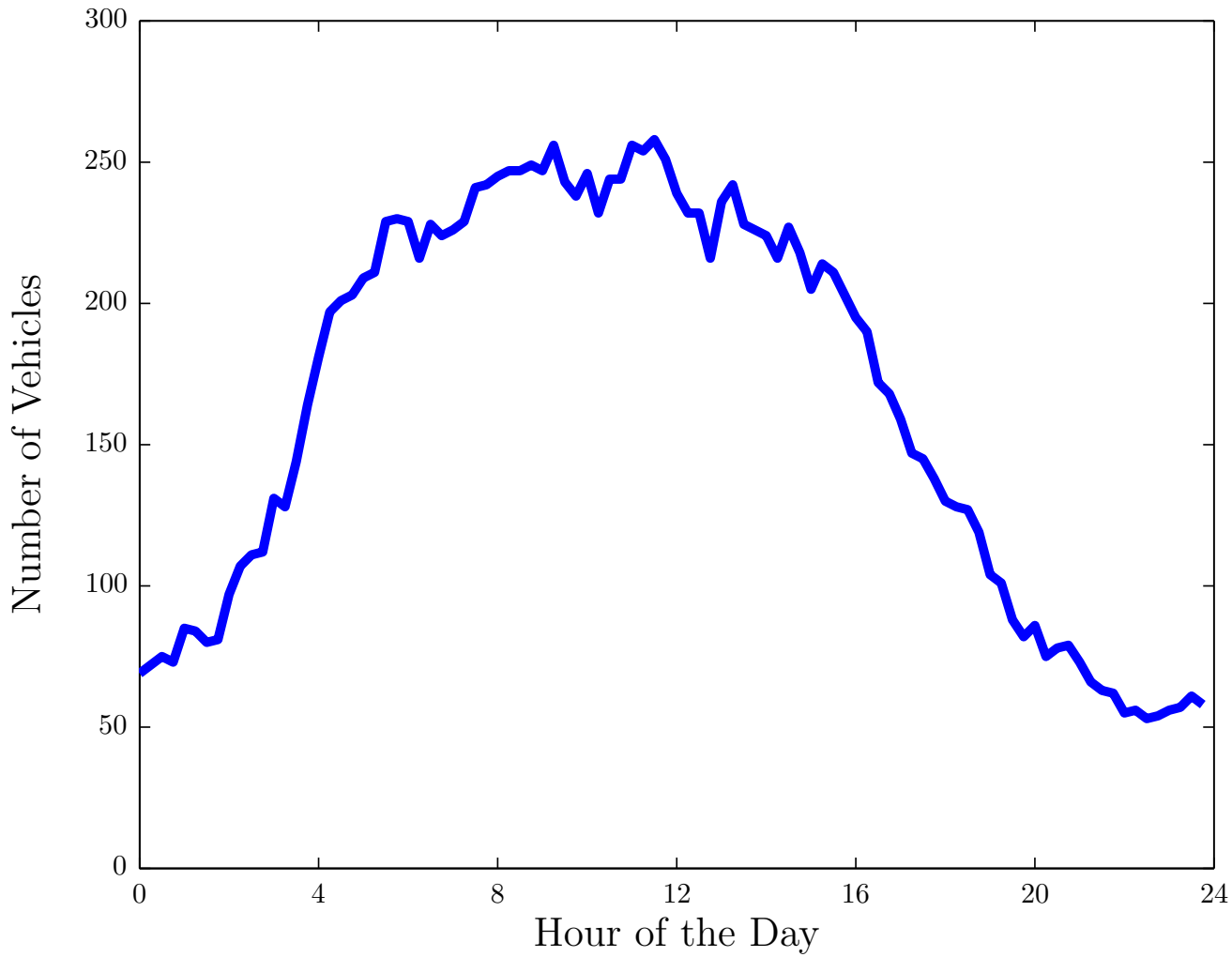
Real-world Data



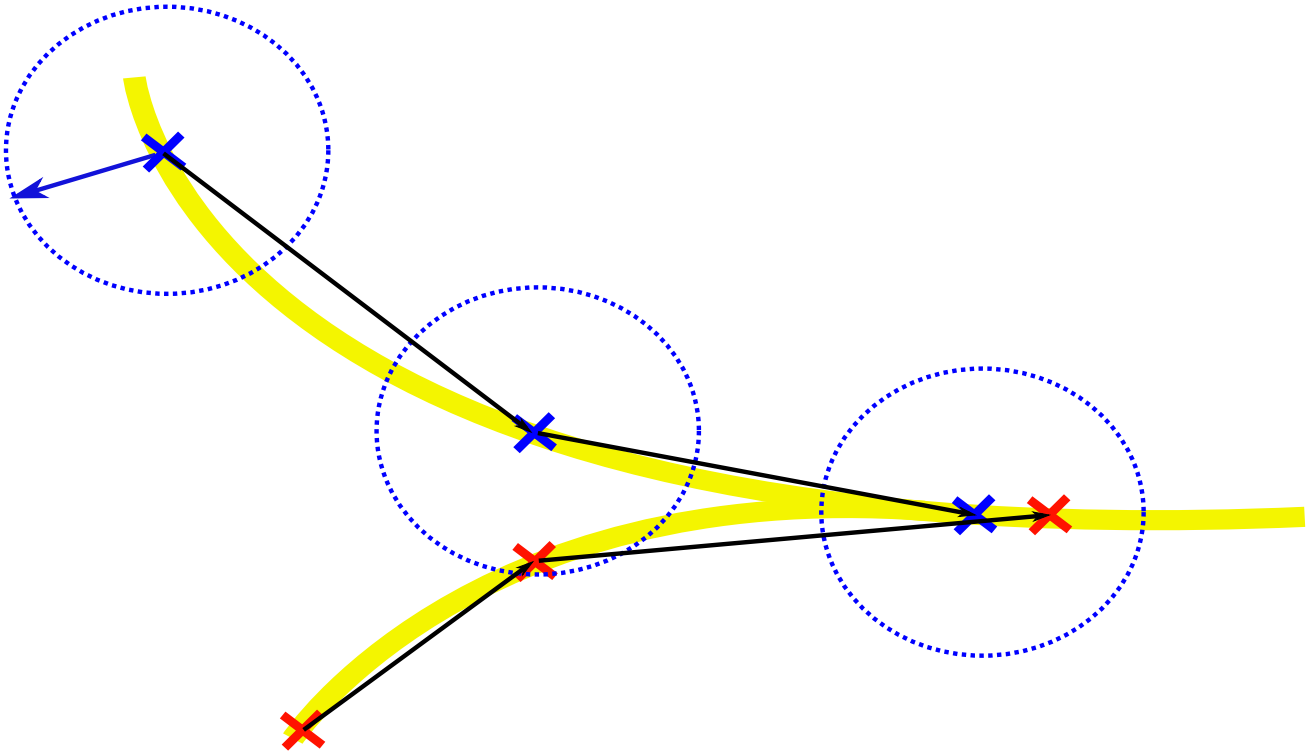
Real-world Data



Real-world Data



Real-world Data



Real-world Data

- $r = 0.2$ km
  - 78 out of 875 vehicles platooned at least once during their daily route.
  - 0.16% of total fuel saved by the platooned vehicles.
  - 585 km platooning out of total 403,413 km driven.
- $r = 1$ km
  - 241 out of 875 vehicles platooned at least once during their daily route.
  - 0.38% of total fuel saved by the platooned vehicles.
  - 4,369 km platooning.
- $r = 5$ km
  - 778 out of 875 vehicles platooned at least once during their daily route.
  - 1.2% of total fuel saved by the platooned vehicles.
  - 43,325 km platooning.

Thank You

COMPANION EU Project: Cooperative Dynamic Formation of Platoons for Safe and Energy-optimized Goods Transportation

Scania, Volkswagen, KTH, OFFIS, IDIADA, S&T AS, Transportes Cerezuela

Thank You

COMPANION EU Project: Cooperative Dynamic Formation of Platoons for Safe and Energy-optimized Goods Transportation

Scania, Volkswagen, KTH, OFFIS, IDIADA, S&T AS, Transportes Cerezuela

Jeffrey Larson - jeffreyl@kth.se